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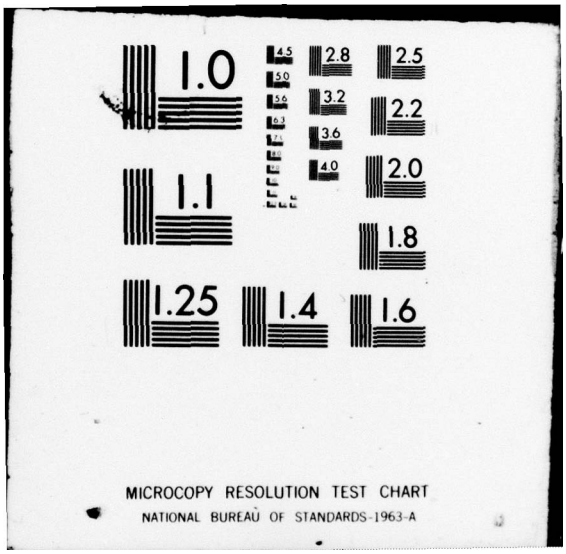
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report presents a summary of a study of amorphous alloys. The study included temper embrittlement of amorphous alloys, creep measurements with a magnetic probe, structural studies, and a computer simulation of the structural defects.

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1. Statement of the Problem

Amorphous alloys obtained by rapid quenching from the melt are beginning to be recognized as important engineering materials because of their excellent mechanical and magnetic properties. Investigations in the last decade or so have revealed many of their intrinsic properties; however, the sensitivity of their physical properties to changes in microstructure has not been extensively studied, although more recent studies have indicated its importance. In particular, for the mechanical applications, the problem of temper embrittlement was one of the most outstanding unresolved problems at the onset of this project.

The problem of embrittlement is not an isolated phenomenon. It should be understood from a much broader and fundamental point of view about the behavior of structural defects in the amorphous state. We undertook at first a study of the embrittlement behavior itself, then a creep and structural study in order to investigate the behavior of the defects in a more direct manner, and some preliminary computer simulation of the atomistic definition of the defect structure.

2. Summary of Research Accomplishments

- Temper Embrittlement: We located the ductile to brittle transition temperature, T_{dbt}, in $Fe_{40}Ni_{40}P_{14}B_6$ alloy by a twist-fracture test, and showed for the first time that T_{dbt} is shifted upward by annealing. The kinetics of this shift were described by a &nt relationship, indicating the importance of structural relaxation in embrittlement.
- Mechanical Creep: By measuring magnetic hysteresis during creep recovery, it was established that long range diffusion plays an important role in the mechanical creep of amorphous alloys. It was also shown that pre-annealing reduces the creep rate, and that the kinetics of structural relaxation explains the creep behavior.
- Structural Study: A computer controlled in-situ energy dispersive X-ray diffraction (EDXD) study of structural relaxation was carried out, confirming an earlier experiment which was not done fully in-situ. The structural change due to deformation by rolling was studied, and it was suggested that the structural change induced by deformation is qualitatively different from that due to structural relaxation.
- Computer Simulation: Structural defects in the amorphous state were studied by a computer simulation technique. The atomic level stresses and symmetry coefficients were computed at each atomic position in a model random structure, and a dislocation-like atomic configuration was identified.

These results demonstrate the importance of structural defects in amorphous alloys, and show that structural relaxation is the

process that eliminates these defects. The next stage of the research is to refine the definition of the defects so that the macroscopically observed behavior can be explained in terms of the microscopically defined defects in a more direct manner. This work has been proposed as a continuation of this project.

3. List of Publications

1. "Temper Embrittlement of Amorphous Alloys", R. S. Williams and T. Egami, in "Rapidly Quenched Metals III", ed. by B. Cantor, vol. 1, 214 (The Metals Society, London, 1978).

2. "Structure of Amorphous Alloys Studied by Energy Dispersive X-ray Diffraction Method", T. Egami, R. S. Williams, and Y. Waseda, ibid, vol. 2, 318 (co-sponsored by NSF).

3. "Effect of Low Temperature Annealing and Deformation on the Structure of Metallic Glasses by X-ray Diffraction", Y. Waseda and T. Egami, J. Mat. Sci., 14 (1979).

4. "Structural Defects in Amorphous Solids Studied by Computer Simulation", K. Maeda, V. Vitek and T. Egami, in preparation.

5. "Effect of Pre-annealing on Mechanical Creep of Amorphous Alloys", T. Egami, H. Kimura, and T. Masumoto, in preparation.

6. "Activation Volume of Structural Defects in Amorphous Alloys", R. S. Williams and T. Egami, in preparation.

4. List of Participating Scientific Personnel

T. Egami - Principal Investigator

C. D. Graham, Jr. - Co-Principal Investigator

R. S. Williams - Research Assistant. Expected to receive a Ph.D. degree in August. Dissertation based upon the research supported by this contract. At present at Westinghouse Research Lab, Pittsburgh.

5. Research Accomplishments

i) Temper Embrittlement of Amorphous Alloys

The details of our results have been described in the earlier reports and in the papers attached, and will not be repeated here. Our observation of the change in the ductile to brittle transition temperature and of the kinetics of this change is the first reported measurement of this phenomenon.

ii) Creep Measurement with Magnetic Probe

We reported earlier that we found a very significant effect of pre-annealing in reducing the creep rate. We also found that the creep has a large $\ln t$ component, a reflection of the kinetics of structural relaxation. However, we were not able to understand the mechanism of creep recovery which occurs when the load is taken off. The recoverable creep is 20-40% of the total creep. In order to understand this phenomenon, we observed the magnetic hysteresis loop during recovery. It was found that the crept sample has a very high internal stress field right after the removal of the load, as evidenced by the large magnetic anisotropy energy of magnetostrictive origin. The stress field then relaxes and disappears as the creep recovery is completed. This observation indicated the presence of a long range flow of matter, driven by the stress gradient, during creep. The creep of amorphous alloys, therefore, is very much like Nabarro-Herring creep in the entire sample rather than within a single grain; that is, there must be a flow of matter from the center of the sample to both ends so that the sample becomes elongated. This conclusion almost eliminates another possible mechanism: that a change of shape of the structural defects

directly contributes to the creep deformation. The latter mechanism involves no long range diffusion, and therefore no internal stress field immediately after the removal of the load.

By changing the load during creep, the activation volume was measured. It was confirmed, as expected, that the change in creep rate is not proportional to the change in load, and the activation volume is found to be about 200 $\mathring{A}^3$, decreasing rather rapidly during the creep process, as we predicted earlier.

iii) Structural Study

The effect of deformation on an as-quenched amorphous sample is rather complex, as noted by Chen[1] and by us[2]. The effect of deformation can be observed in isolation when an annealed sample is deformed. However, most of the amorphous alloys become brittle after annealing, so that it is difficult to deform them heavily after annealing. $Pd_{80}Si_{20}$ allows such a deformation, since it does not embrittle. Pd, however, makes the EDXD measurement very difficult because its absorption edge is right in the middle of the energy range used for analysis. Therefore a conventional diffraction technique was used to study the effect of deformation, in collaboration with Y. Waseda of Toronto University. The result indicated that the structural defects introduced by deformation are qualitatively different from those annealed out during structural relaxation. The study, however, is not quite conclusive, and further study using Pt-Ni-P is planned.

iv) Computer Simulation of Structural Defects

All the results obtained in this project point to the existence of structural defects in amorphous alloys. Such a claim,

however, is meaningless without a legitimate microscopic definition of the defects in the amorphous state. By computing the internal stresses and the point symmetry coefficients of each atom in a model amorphous structure, we made significant progress in this regard. It was found that a group of atoms sometimes take on arrangements closer to the crystalline state, or to the lattice dislocations, when we compare these quantities. Our next step is to investigate the response of these defects to external stresses.

References

1) H. S. Chen, Scripta Met., 9, 411 (1975).

2) R. S. Williams and T. Egami, IEEE Trans. Mag., MAG-12, 927 (1976).